Claims

[c1] A method of forming an interconnect structure on a substrate, the method comprising the steps of:
depositing at least one dielectric layer on the substrate, the dielectric layer being formed of at least one first dielectric material;
embedding at least one conductive interconnect in the dielectric layer, the conductive interconnect having sidewalls in contact with the first dielectric material;
removing a portion of the first dielectric material in selected areas of the dielectric layer, thereby forming at least one opening in the dielectric layer, such that the sidewalls of the conductive interconnect remain in contact with the first dielectric material; and
filling the opening with a second dielectric material.

[c2] The method of Claim 1, wherein the second dielectric material has a dielectric constant less than that of the first dielectric material.

[c3] The method of Claim 1, wherein the second dielectric material has a dielectric constant less than about 4.0.

[c4] The method of Claim 1, wherein the second dielectric

material has a dielectric constant of about 1.3 to about 3.5.

[c5] The method of Claim 1, wherein the first dielectric material comprises a material selected from the group consisting of SiO_2, FSG and SiCOH, and the second dielectric material comprises a material selected from the group consisting of amorphous carbon, fluorinated amorphous carbon, parylene, boron nitride, teflon, polynapthalene-N, polynapthalene-F, polyarylene ether, fluorinated polyamide, fluorocyclobutene, perfluorocyclobutene, benzocyclobutene, methylsilsesquioxane, hydrosilsesquioxane, polyarylene ethers, fluorpolymers, polyamide nanofoam, silica aerogel, fully cyclized heterocyclic polymers, SiCOH and porous SiCOH.

[c6] The method of Claim 1, wherein the second dielectric material includes at least one void.

[c7] The method of Claim 1, wherein the second dielectric material is a porous dielectric material.

[c8] The method of Claim 1, wherein the conductive interconnect is formed of copper.

[c9] The method of Claim 1, wherein the second dielectric material has a dielectric constant greater than that of the first dielectric material.

[c10] The method of Claim 1, wherein the conductive interconnect has a top surface coplanar with the top surface of the dielectric layer; and
wherein the portion of the first dielectric material is removed by a method comprising the steps of:
forming a cap on each conductive interconnect, the cap having a lateral extent greater than that of the conductive interconnect, thereby masking portions of the dielectric layer adjacent to the conductive interconnect and leaving other portions of the dielectric layer not masked; and
removing a portion of the first dielectric material in areas of the dielectric layer not masked by the cap, thereby forming the at least one opening in the dielectric layer.

[c11] The method of Claim 10, wherein the cap is formed of CoNiP or CoWP, and is formed by selective electroless plating.

[c12] The method of Claim 10, wherein the cap is formed of tungsten, and is formed by selective CVD metal deposition.

[c13] The method of Claim 10, wherein the cap has a lateral extent of about 10 nm to about 50 nm greater than that of the conductive interconnect.

[c14] The method of Claim 1, wherein the conductive interconnect has a top surface and sidewalls, and the top surface is higher than the top surface of the first dielectric material, thereby exposing a top portion of the sidewalls; and
wherein the portion of the first dielectric material is removed by a method comprising the steps of:
forming a cap on the top surface and exposed sidewalls of each conductive interconnect, the cap having a lateral extent greater than that of the conductive interconnect, thereby masking portions of the dielectric layer adjacent to each conductive interconnect and leaving other portions of the dielectric layer not masked; and
removing a portion of the first dielectric material in areas of the dielectric layer not masked by the cap, thereby forming the at least one opening in the dielectric layer.

[c15] The method of Claim 14, wherein the top surface of the conductive interconnect is initially coplanar with the top surface of the first dielectric material, and the top surface of the conductive interconnect is made higher than the top surface of the first dielectric material by removing a top portion of the first dielectric material, thereby recessing the top surface of the first dielectric material below the top surface of the conductive interconnect and exposing a top portion of the sidewalls of the conductive

interconnect.

[c16] The method of Claim 14, wherein the cap is formed of CoNiP or CoWP, and is formed by selective electroless plating.

[c17] The method of Claim 14, wherein the cap is formed of tungsten, and is formed by selective CVD metal deposition.

[c18] The method of Claim 14, wherein the top surface of the conductive interconnect is about 10 nm to 300 nm higher than the top surface of the first dielectric material.

[c19] The method of Claim 15, wherein the top surface of the conductive interconnect is made higher than the top surface of the first dielectric material by removing a top portion of about 10 nm to about 300 nm of the first dielectric material.

[c20] The method of Claim 14, wherein the cap has a lateral extent of about 10 nm to about 50 nm greater than that of the conductive interconnect.

[c21] The method of Claim 1, wherein the at least one dielectric layer comprises a layer of a first dielectric material deposited on the substrate and a layer of a third dielec-

tric material deposited on the layer of first dielectric material; and

wherein the conductive interconnect is embedded in the dielectric layer by a method comprising the steps of:

forming at least one first opening in the layers of first and third dielectric materials;

removing portions of the layer of third dielectric material adjacent to the first opening, thereby exposing portions of the top surface of the layer of first dielectric material; and

filling the first opening with a conductive material, thereby forming at least one conductive interconnect, the conductive interconnect having a top surface coplanar with the top surface of the layer of third dielectric material, and a top portion having a lateral extent greater than that of lower portions of the conductive interconnect, thereby masking portions of the layer of first dielectric material adjacent to each conductive interconnect and leaving the layer of third dielectric material and other portions of the layer of first dielectric material not masked; and

wherein the portion of the first dielectric material is removed by a method comprising the step of:

removing the layer of third dielectric material and a portion of the first dielectric material in areas of the layer of first dielectric material not masked by the top portion of

the conductive interconnect, thereby forming at least one second opening in the dielectric layer.

[c22] The method of Claim 21, wherein the third dielectric material has an etch rate greater than that of the first dielectric material; and the step of removing portions of the third dielectric layer adjacent to the first opening is performed by exposing the structure to an etch.

[c23] The method of Claim 22, wherein the etch is an isotropic etch comprising hydrofluoric acid.

[c24] The method of Claim 22, wherein the third dielectric material has an etch rate about 30 times greater than that of the first dielectric material.

[c25] The method of Claim 22, wherein a lateral portion of about 20 nm of the third dielectric layer is removed.

[c26] The method of Claim 21, the third dielectric material comprises a material selected from the group consisting of PSG, BPSG and ozone/TEOS SiO_2.

[c27] The method of Claim 21, wherein the layer of third dielectric material has a thickness of about 10 nm to about 100 nm.

[c28] The method of Claim 21, wherein the top portion of the conductive interconnect has a lateral extent of about 10

nm to about 50 nm greater than that of lower portions of the conductive interconnect.

[c29] The method of Claim 21, further comprising the step of removing the top portion of the conductive interconnect and a top portion of the second dielectric material, such that the top surface of the conductive interconnect is made coplanar with the top surface of the first portion and the top surface of the second portion.

[c30] The method of Claim 1, wherein the conductive interconnect is embedded in the dielectric layer by a method comprising the steps of:
forming at least one first opening in the dielectric layer;
removing a top portion of the dielectric material adjacent to the first opening, thereby rounding top corners of the first opening; and
filling the first opening with a conductive material, thereby forming at least one conductive interconnect, the conductive interconnect having a top surface coplanar with the top surface of the dielectric layer, and a top portion having a lateral extent greater than that of lower portions of the conductive interconnect, thereby masking portions of the dielectric layer adjacent to the conductive interconnect and leaving other portions of the dielectric layer not masked; and
wherein the portion of the first dielectric material is re-

moved by a method comprising the step of:
removing a portion of the first dielectric material in areas of the dielectric layer not masked by the top portion of the conductive interconnect, thereby forming at least one second opening in the dielectric layer.

[c31] The method of Claim 30, wherein the top corners of the first opening are rounded by a sputter pre-clean using Ar or Ar/H_2.

[c32] The method of Claim 30, wherein the top corners of the first opening are rounded by exposing the structure to an isotropic etch.

[c33] The method of Claim 30, wherein the top portion of the conductive interconnect has a lateral extent of about 10 nm to about 50 nm greater than lower portions of the conductive interconnect.

[c34] The method of Claim 30, further comprising the step of removing the top portion of the conductive interconnect and a top portion of the second dielectric material, such that the top surface of the conductive interconnect is made coplanar with the top surface of the first portion and the top surface of the second portion.

[c35] An interconnect structure formed on a substrate, the structure comprising:

an interconnect layer comprising at least one first portion and at least one second portion, the first portion comprising a first dielectric material and having a bottom surface, sidewalls and a top surface, and the second portion comprising a second dielectric material and having a bottom surface, sidewalls and a top surface, wherein the sidewalls of the second portion are in contact with the first portion; and

at least one conductive interconnect embedded in the first portion, the conductive interconnect having sidewalls in contact with the first dielectric material but not in contact with the second dielectric material.

[c36] The interconnect structure of Claim 35, wherein the top surface of the first portion and the top surface of the second portion are coplanar, and the conductive interconnect has a top surface coplanar with the top surface of the interconnect layer.

[c37] The interconnect structure of Claim 35, wherein the bottom surface of the first portion and the bottom surface of the second portion are coplanar and are in contact with the substrate.

[c38] The interconnect structure of Claim 35, wherein the second dielectric material has a dielectric constant less than that of the first dielectric material.

[c39] The interconnect structure of Claim 35, wherein the second dielectric material has a dielectric constant less than about 4.0.

[c40] The interconnect structure of Claim 35, wherein the second dielectric material has a dielectric constant of about 1.3 to about 3.5.

[c41] The interconnect structure of Claim 35, wherein the first dielectric material comprises a material selected from the group consisting of SiO_2, FSG and SiCOH, and the second dielectric material comprises a material selected from the group consisting of amorphous carbon, fluorinated amorphous carbon, parylene, boron nitride, teflon, polynapthalene-N, polynapthalene-F, polyarylene ether, fluorinated polyamide, fluorocyclobutene, perfluorocyclobutene, benzocyclobutene, methylsilsesquioxane, hydrosilsesquioxane, polyarylene ethers, fluorpolymers, porous dielectrics, polyamide nanofoam, silica aerogel, and fully cyclized heterocyclic polymers.

[c42] The interconnect structure of Claim 35, wherein the second dielectric material includes at least one void.

[c43] The interconnect structure of Claim 35, wherein the second dielectric material is a porous dielectric material.

[c44] The interconnect structure of Claim 35, wherein the conductive interconnect is formed of copper.

[c45] The interconnect structure of Claim 35, wherein the second dielectric material has a dielectric constant greater than that of the first dielectric material.

[c46] The interconnect structure of Claim 35, further comprising:
at least one cap overlying the first portion and the conductive interconnect but not overlying the second portion, and having a lateral extent greater than that of the conductive interconnect, such that the top surface of the first portion is in contact with the cap but the top surface of the second portion is not in contact with the cap.

[c47] The interconnect structure of Claim 46, wherein the cap has a top surface coplanar with the top surface of the second portion.

[c48] The interconnect structure of Claim 46, wherein the cap is formed of CoNiP or CoWP.

[c49] The interconnect structure of Claim 46, wherein the cap is formed of tungsten.

[c50] The interconnect structure of Claim 46, wherein the cap has a lateral extent of about 10 nm to about 50 nm

greater than that of the conductive interconnect.

[c51] The interconnect structure of Claim 35, wherein the conductive interconnect has a top surface coplanar with the top surface of the second portion, and the conductive interconnect has a top portion having a lateral extent greater than lower portions of the conductive interconnect, such that the top surface of the first portion is in contact with the top portion of the conductive interconnect but the top surface of the second portion is not in contact with the conductive interconnect.

[c52] The interconnect structure of Claim 51, wherein the top portion of the conductive interconnect has a lateral extent of about 10 nm to about 30 nm greater than lower portions of the conductive interconnect.